

CLAIMS:

1. An expandable shaft comprising:
 - an inner shaft having an outer peripheral surface;
 - a tubular outer shaft having an inner peripheral surface
 - 5 and being fit over the inner shaft to be fit therein;
 - at least one raceway groove formed on the outer peripheral surface of the inner shaft to extend longitudinally;
 - at least one raceway groove formed on the inner surface of the outer shaft to oppose the raceway groove of the inner
 - 10 shaft; and
 - plural rolling elements pinched elastically in a space between the raceway grooves of the inner shaft and the outer shaft by an elastic restoring force of the outer shaft, wherein
 - 15 the plural rolling elements are aligned in an array along a longitudinal direction of the raceway grooves,
 - the outer peripheral surface of the inner shaft includes at least a pair of flat portions that are parallel to each other,
 - the inner peripheral surface of the outer shaft includes
 - 20 at least a pair of flat limiting portions that are parallel to each other,
 - the limiting portions limit a quantity of relative rotation of the inner shaft and the outer shaft by engaging, respectively, with the corresponding flat portions,
 - 25 the outer shaft includes a deformation promoting portion

that promotes deformation of the outer shaft,

the deformation promoting portion is placed in a specific region of the outer shaft in a circumferential direction, and

the specific region is a region between a plane including
5 a center of curvature of the raceway groove of the outer shaft
as well as a central axis line of the outer shaft and each
limiting portion.

2. The expandable shaft according to Claim 1, wherein
10 the deformation promoting portion includes at least one
bending portion.

3. The expandable shaft according to Claim 1, wherein
the deformation promoting portion includes plural
15 bending portions, and the specific region of the outer shaft
thereby shapes a waveform.

4. The expandable shaft according to Claim 1, wherein
the outer shaft includes a relatively thick portion and
20 a relatively thin portion, and
the deformation promoting portion includes the
relatively thin portion.

5. The expandable shaft according to Claim 1, wherein
25 the inner shaft is provided with a protrusion having a

rectangular cross section that protrudes outward in a radial direction of the inner shaft,

the outer shaft is provided with a concave portion having a rectangular cross section that accommodates the protrusion,

5 the flat portions include a flat portion provided on an outer surface of the protrusion of the inner shaft, and

the limiting portions include a limiting portion provided on an inner surface of the concave portion of the outer shaft.

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6. The expandable shaft according to Claim 5, wherein

the outer shaft is provided with a protrusion having a rectangular cross section that protrudes outward in a radial direction of the outer shaft, and

15 the concave portion is formed on an inner side of the protrusion of the outer shaft.

7. The expandable shaft according to Claim 6, wherein:

a bending portion is provided in a base end portion of
20 the protrusion of the outer shaft as the deformation promoting portion.

8. The expandable shaft according to Claim 5, wherein

two raceway grooves and two protrusions are provided on
25 the inner shaft,

the two protrusions oppose each other in the radial direction of the inner shaft,

the outer shaft is provided with two concave portions, the respective protrusions are accommodated in the
5 corresponding concave portions, and

a direction in which the two protrusions oppose each other and a direction in which the two raceway grooves of the inner shaft oppose each other are directions that intersect with each other at right angles.

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9. The expandable shaft according to Claim 1, wherein the outer shaft is shaped like a star by including plural bending portions that are placed apart at intervals in a circumferential direction to tilt alternately in opposite
15 directions.

10. The expandable shaft according to Claim 1, wherein the outer shaft comprises a tube of substantially a square shape, and

20 the raceway groove of the outer shaft is formed at each corner in at least a pair of opposing corners of the tube of the square shape.

11. The expandable shaft according to Claim 10, wherein
25 protrusions that protrude outward in a radial direction

are provided at the pair of corners provided with the raceway grooves, and

a bending portion is formed at a base end portion of each protrusion as the deformation promoting portion.

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12. The expandable shaft according to Claim 10 further comprising:

a tubular holder that surrounds a periphery of the inner shaft,

10 wherein the rolling elements in arrays corresponding to the respective raceway grooves are held by the holder.

13. The expandable shaft according to Claim 1 further comprising:

15 at least a pair of stoppers provided in end portions of the inner shaft and the outer shaft to prevent the rolling elements from falling off from the raceway grooves,

wherein the pair of stoppers include a pair of plastic deformation portions provided in the inner shaft and the outer
20 shaft.

14. The expandable shaft according to Claim 1, wherein the rolling elements include balls having a diameter of 10 to 40% of an outside diameter of the outer shaft.

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15. The expandable shaft according to Claim 14, wherein
a thickness of the outer shaft is 5 to 15% of the outside
diameter of the outer shaft.

5 16. The expandable shaft according to Claim 14, wherein
a contact angle of the balls is in a range from 5 degrees
to 40 degrees.

17. The expandable shaft according to Claim 1, wherein
10 a central angle of the outer shaft corresponding to the
specific region is in a range from 30 degrees to 60 degrees.

18. The expandable shaft according to Claim 1, wherein:
a central angle of the outer shaft corresponding to the
15 specific region is in a range from 40 degrees to 50 degrees.

19. The expandable shaft according to Claim 1, wherein
a central angle of the outer shaft, which corresponds
to a region between the plane including the center of curvature
20 of the raceway groove of the outer shaft as well as the central
axis line of the outer shaft and the deformation promoting
portion, is in a range from 30 degrees to 60 degrees.

20. The expandable shaft according to Claim 1, wherein
25 a central angle of the outer shaft, which corresponds

to the plane including the center of curvature of the raceway groove of the outer shaft as well as the central axis line of the outer shaft and the deformation promoting portion, is in a range from 40 degrees to 50 degrees.

5 21. the expandable shaft according to Claim 1, wherein

the outer shaft comprises a pair of opposing portions that oppose each other in a radial direction of the outer shaft,

the pair of opposing portions are a circular arc in cross section abut the central axis line of the outer shaft,

10 the outer shaft comprises a pair of remaining portions disposed between the pair of opposing portions in the circumferential direction of the outer shaft,

the raceway grooves of the outer shaft comprise a raceway groove formed on an inner peripheral surface of one remaining
15 portion and the other raceway groove formed on an inner peripheral surface of the other remaining portion,

the limiting portions of the outer shaft comprise a pair of limiting portions formed on the inner peripheral surface of the one remaining portion and a pair of limiting portions
20 formed on the inner peripheral surface of the other remaining portion.

22. The expandable shaft according to Claim 21, wherein a central angle of the outer shaft corresponding to the pair of opposing portions is in a range from 70 degrees to 110
25 degrees.

23. The expandable shaft according Claim 22, wherein a central angle of the outer shaft corresponding to the specific region is in a range from 15 degrees to 25 degrees.